STRUCTURE OF FLAVYLIUM SALTS

BY
ROBERT BRUCE MOFFETT
A.B., Hanover College, 1937
M.A., University of Illinois, 1939

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SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN
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Introduction

One of the classes of natural organic coloring matters consists of a group of closely related compounds called anthocyanins. Previous studies have shown that these compounds contain a reactive (probably ionic) chlorine atom and that they are polyhydroxy (or methoxy) derivatives of the class of compounds known as 2-phenylbenzopyrylium salts or flavylium salts. The point of attachment of the chlorine atom, the nature of the bond, and the position of the double bonds in the molecule have been the subject of much speculation.

The purpose of this investigation was to determine which of the several suggested structures is correct. To this end the following lines of evidence have been investigated: (1) synthesis from substituted coumarins and chromones; (2) ozonization of the flavylium salts and their alkoxy derivatives; (3) nitration of 3-phenylflavylium perchlorate; and (4) conductivity and molecular weight determinations.

Historical

The carbon and oxygen skeleton structure of the flavylium salts has long been regarded as established, but many different arrangements of the double bonds and positions occupied by the positive charge have been suggested. Two of these postulate oxonium structures, with and without an ortho quinoid group. Two postulate carbonium structures, with the positive charge either on the 2 or 4 carbon atoms. Two theories postulate the para quinoid arrangement, and two postulate centric or para bonds. A review of the synthesis and structure of the benzopyrylium salts has been contributed by Hill.[1]

Theoretical and Experimental

All methods of synthesis of benzoprylium salts have so

far yielded only a single salt, even when methods were employed which might be expected to lead to two isomeric structures. This indicates that an allylic shift must take place. Thus treatment of 3-phenyl-4-(*p*-tolyl)-6-methylcoumarin with phenylmagnesium bromide yielded 2,3-diphenyl-4-*p*-tolyl)-6-methyl-1,2-benzopyran-2-ol, which was converted to 3-phenyl-4-(*p*-tolyl)-6-methylflavylium perchlorate, ferrichloride and chloride hydrochloride. These same salts were also obtained from 2,3-diphenyl-4-(*p*-tolyl)-6-methyl-1,4-benzopyran-4-ol, which was synthesized by the reaction between *p*-tolylmagnesium bromide and 2,3-diphenyl-6-methylchromone. This agrees with the work of Ziegler, Fries and Sälzer[2] who obtained the two corresponding pyranols by the action of phenylmagnesium bromide on 2,3-diphenyl-6-methylchromone and on 3,4-diphenyl-6-methylcoumarin. The pyranol-4 (from the former) could be easily converted to the pyranol-2 (from the latter) either by heat or by conversion to 3,4-diphenyl-6-methylflavylium perchlorate followed by hydrolysis.

Similarly Löwenbein[3] obtained only a single 4-phenylflavylium salt by oxidation with ferric chloride of both 2,4-diphenyl-$\triangle^2$-chromene and 2,4-diphenyl-$\triangle^3$-chromene. Many condensations by hydrogen chloride of *o*-hydroxybenzaldehydes with substituted acetophenones have all yielded only one salt.

By hydrogen peroxide oxidation of flavylium salts, Dilthey and Quint, and Dilthey and Höschen[4] obtained products which showed that the ring was cleaved between the 2 and 3 carbon atoms.

In this investigation it was found that ozonolysis of 3-methoxy-4′-bromoflavylium chloride hydrochloride yields salicylaldehyde, *p*-bromobenzoic acid, and methyl *o*-(*p*-bromobenzoxy)-α-toluate; that ozonolysis of 3-phenyl-4′-bromoflavylium chloride hydrochloride yields salicylaldehyde, *p*-bromobenzoic acid, and 4-bromobenzil; and that ozonolysis of 3-phenylflavylium chloride hydrochloride yields salicylaldehyde, α-(*o*-benzoxyphenyl)-acteophenone and benzoic acid. This leads to the conclusion that these salts may be cleaved between

either the 2 and 3 carbon atoms or the 3 and 4 carbon atoms, and therefore must exist in two forms in resonance.

It has been shown[5] that bromine atoms in the 4′ or 7 positions of 3-methoxyflavylium salts are not active towards silver nitrate, silver chloride, or molecular silver and therefore these salts do not exist in *p*-quinoid forms.

Löwenbein[3] has shown that flavylium salts undergo a simple coupling reaction with Grignard reagents whereby the R group of RMgX may become attached to either the 2 or 4 carbon atom, which indicates the positive charge of the salts may be on either of these atoms.

Many workers have observed that water or alcohols react easily with flavylium salts to give pyranols or their ethers. In this investigation ozonolysis of the ethoxy derivative from 3-phenyl-4′-bromoflavylium chloride hydrochloride yielded salicylaldehyde, 4-bromobenzil, and ethanol, showing that the ethoxy group is on the 2 carbon atom.

Nitration of 3-phenylflavylium perchlorate yielded, under mild conditions, 3-(*p*-nitrophenyl)-flavylium perchlorate and under more vigorous conditions 3-(*p*-nitrophenyl)-3′-nitroflavylium perchlorate, which indicates that the 2 carbon atom must be relatively positive and the 3 carbon atom relatively negative.

This agrees with the work of LeFèvre[6] who studied the nitration of a number of flavylium, pyrylium, and xanthylium salts.

Conductivity and molecular weight measurements on a number of flavylium perchlorates and ferrichlorides showed that these compounds are ionized in nitrobenzene, and that they are very similar to triphenylcarbinol perchlorate in this respect, but quite different from dimethyl-8-pyrone hydrochloride which is only very slightly ionized. The flavylium chloride hydrochlorides were found to give quite differently shaped curves.

Summary

1. Treatment of 2-phenyl-4-(*p*-tolyl)-6-methylcoumarin

with phenylmagnesium bromide yielded a substituted pyranol-2 which was converted to 6-methyl-3-phenyl-4-(*p*-tolyl)-flavylium perchlorate, ferrichloride and chloride hydrochloride. These same salts were also obtained from 2,3-diphenyl-4-(*p*-tolyl)-6-methyl-1,4-benzopyran-4-ol which was synthesized by the reaction between *p*-tolylmagnesium bromide and 6-methyl-2,3-diphenylchromone.

2. Ozonolysis of two flavylium salts, 3-methoxy-4′-bromoflavylium chloride hydrochloride and 3-phenyl-4′-bromoflavylium chloride hydrochloride yielded degradation products whose formation indicated that these salts may be cleaved between either carbon atoms 2 and 3 or carbon atoms 3 and 4.

3. A number of alkoxy derivatives of flavylium salts have been prepared and ozonolysis of 2-ethoxy-2-(*p*-bromophenyl)-3-phenyl-1,2-benzopyran, and of 2-methoxy-2,3-diphenyl-4-(*p*-tolyl)-6-methyl-1,2-benzopyran indicated that these compounds were split between the 3- and 4-carbon atoms.

4. Nitration of 3-phenylflavylium perchlorate yielded under mild conditions 3-(*p*-nitrophenyl)-flavylium perchlorate and under more vigorous conditions 3-(*p*-nitrophenyl)-3′-nitroflavylium perchlorate, which indicate that the 2-carbon atom is relatively positive and the 3-carbon relatively negative.

5. Conductivity and molecular weight measurements on a number of flavylium salts shows them to be ionized in nitrobenzene.

6. These results together with the evidence in the literature suggest that the simple flavylium salts contain a resonating allylic system.

Bibliography

1. Hill, Chem. Rev., *19,* 27 (1936).
2. Ziegler, Fries and Sälzer, Ann., *448,* 249 (1926).
3. Löwenbein, Ber. *57,* 1517 (1924).
4. Dilthey and Quint, J. prakt. Chem., *131,* 1 (1931); Dilthey and Höschen, *ibid., 138,* 42 (1933).
5. Shriner and Moffett, J. Am. Chem. Soc., *61,* 1474 (1939).
6. LeFèvre, J. Chem Soc., *1929,* 2771; LeFèvre and LeFèvre, *ibid., 1932,* 2894; LeFèvre and Pearson, *ibid, 1933,* 482; LeFèvre, LeFèvre and Pearson, *ibid, 1934,* 37.

VITA

The author was born on June 8, 1914 at Madison, Indiana. He attended the public schools in that city and graduated from Madison High School in 1933. In June 1937 he received the degree of Bachelor of Arts from Hanover College. In September of the same year he entered the University of Illinois as a graduate assistant, which position was held for two years, and in February 1939 he received the degree of Master of Arts. In 1939 and in 1940 he was granted graduate fellowships.

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